Defense Technical Information Center Compilation Part Notice

ADP011339

TITLE: The Face Recognition Security Entrance

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: Input/Output and Imaging Technologies II. Taipei, Taiwan, 26-27 July 2000

To order the complete compilation report, use: ADA398459

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP011333 thru ADP011362

The Face Recognition Security Entrance

C. W. Ni[1]
Opto-Electronics & Systems Laboratories
Chutung, Taiwan, Republic of China

ABSTRACT

This paper describes an automatic face recognition algorithm for security entrances. There are two major steps in this procedure to make the automatic recognition possible:

1. We combined the two-phase face detection method and back propagation neural networks to detect human faces when people are walking in the region of entrances. The combination allows the strength of both methods activated to accommodate the size and head-orientation variations and to eliminate the false detection.
2. Novel face recognition: we extract the facial feature measurements to form the multi-variable normal distribution for each person. These multi- variable normal distributions separate the decision space well and the probability for good index for face recognition.

This face recognition algorithm is very efficient on computing time and taking little storage space.

Keywords: Face Recognition, Feature Extraction, Back Propagation Neural Networks, Multi-variable Normal Distribution

1. INTRODUCTION

We design a security entrance to allow authorized personnel un-interruptedly walking into the entrance. The user's face image was taken during the early stage in the one's entering. The one's facial information is analyzed and identified from the authorized personnel database. Currently, there exist security systems designed with the combination of the password and the face recognition. But only a face recognition technique, which may work in clustered moving backgrounds and can recognize the face from a database, is able to provide user-friendly applications.

The field of face detection and face recognition have increasingly attracted researchers' interest over the past a few years. While the face detection is the foundation of face recognition. For human intelligence, the face detection is a easy task; but for the artificial intelligence, it takes quiet a while to do the computing to detect a face. There are several face detection and face recognition image processing techniques under development[1]: neural network based technique[2-4], feature-based technique[5-6], the view-based eigenspaces technique[7-9], the elastic matching technique[10,12], three-dimensional surface-based approaches[11], and face recognition using Hidden Markov Models[13].

The Neural network-based algorithms[2-4] reported fair results. Lin *et al.* used a Probabilistic Decision-Based Neural Network approach reported fast and nearly 100% recognition rate. Lawrence *et al*, combined a self-organizing map neural network and a convolutional neural networks. Rowley *et al* first did the histogram equalization to correct lighting variations, and employed various window sizes and different subsampling ratio to detect all possible faces, 90.5% recognition rate was achieved.

The feature-based[5-6] face recognition by fitting deformable templates to face regions to extract the face feature geometry, then to normalize them for standardization. Normalized features are classified by a set of principle eigenvectors. The representation vectors of this classification can be mapped to the facial features independent of the facial expressions.

[1] Further author information -
Email: cwni@oes.itri.org.tw

In *Input/Output and Imaging Technologies II*, Yung-Sheng Liu, Thomas S. Huang, Editors, Proceedings of SPIE Vol. 4080 (2000) • 0277-786X/00/$15.00

Shackleton *et al* used six potential energy terms to include all variables, in an iteration process of templates fitting, iteratively modifying all parameters. But this method didn't reach very high recognition rate. Cox *et al*, therefore, adopted a mixture-distance techniques, each face represented by 30 distances calculated from 35 measured positions, reached 95% recognition rate.

The view-based eigenspaces[7-9] assumes that the set of all possible face patterns occupies a small and parameterized subspace. The approach approximates the subspace of face patterns using data clusters and principal components from one or more example sets of face images. An advantage of eigenspace approaches is that it is possible to deal with occluded situations. The approach is only demonstrated to be working in un-clustered background. With the likelihood estimate which can be made optimal (with respect to information-theoretic divergence) and can be computed solely from the low-dimension subspace projection coefficients, thus yielding a computationally efficient estimator for high density probability density function. The eigenfaces face detection technique is a fast, simple, and practical method. But the detection highly depends on the high correlation between the training images and the test images.

The elastic matching technique, employs the Gabor decomposition, accommodates a shift, dilation or local transformations (such as head tilting or smiling)[11]. The Gabor decomposition of an object image I(x), obtained by convolving it with the complex Gabor filter kernels $G_{\Psi(k,l)}$ is an iconic multiresolution template. To reduce the interpixel redundancy, subsampling this template forms a Gabor grid $\mathcal{G} = \{V', E'\}$ that covers the object with N*M nodes (vertices V') in the x and y directions, and edges (E'), respectively. The magnitude of the Gabor probe is used to measure the similarity between matched local features, while the phase of Gabor probe is used to fine tune the matching result. The extracted information (both signal energy and local pattern structure) associated with each probe spans a multiresolution neighborhood whose size equals the extent of the filter kernels. Each Gabor probe records Gabor decomposition of an object at a spatial location x with spectral extent $\Delta\omega_k$. It also represents the fact that the low-frequency channel extracts coarse image features in a large neighborhood, while high-frequency channel can extract fine localized features in a small neighborhood. The grid node records the localized feature at each spatial location, and the grid-edge records the spatial relationship between nodes[11].

The three-dimensional surface-based approach model the frontal (physical) human faces as a 3D surface and recover it from its 2D image with 3D eigen head of eigensurfaces values which obtained from the laser scans of human faces. The eigen head method can exclude the lighting condition variations, but it cannot not deal effectively with rotation[10]. The Hidden Markov Model, with the combination with neural networks, applied on face recognition[13] reported 100% recognition rate. The newly developed algorithms have the charicter that combine several methods such that each method can take advantage of its strength, and the slightly overlapped calculation insures better algorithm robustness.

2. THE FACE RECOGNITION ALGORITHM

By analyzing the image taken from the CCD and matching with the data base of the authorized personnel , the user's access of the security entrance is authorized (Figure 1). Since the analyzing images are taken in a region in front of the entrance, the sizes of the face images have both upper and lower bound. We adapt the Two-Phase face detection algorithm to catch a suitable size of a face in a clustered background. This detection algorithm tolerates some face size and orientation variations, but not quite enough for the image of a walking user stepping into our entrance.

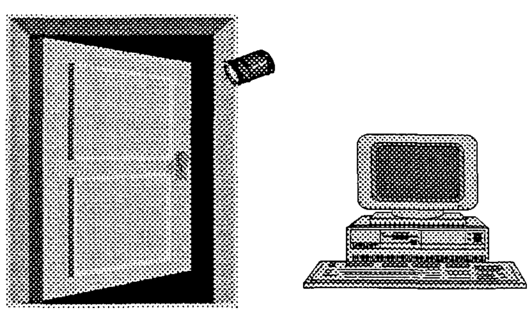

Fig. 1

In order to catch all possible size of face images in the defined region, for a fixed size of template, the images are subsampled into different resolutions. To accommodate user head's tilting, in the image taken processes, the images are rotated in each admissible angle. The two-phase face detection algorithm[1] is employed for each size and each angle of images (Figure 2).

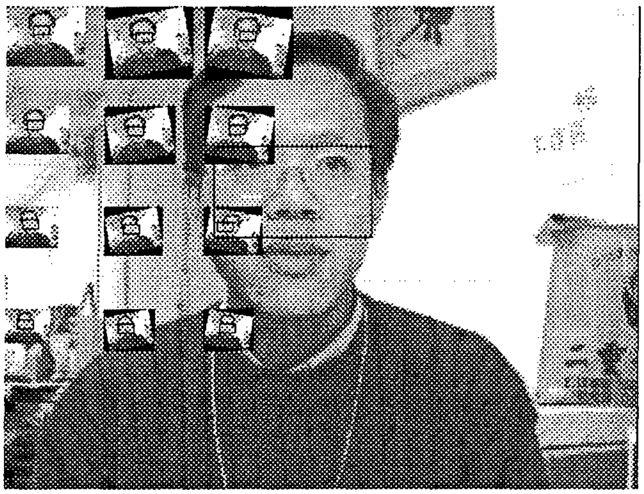

Fig. 2

Then we send the set of detected faces into a pre-trained back propagation neural networks to find the best faces in terms of face sizes and face orientations. In Figure 2, the best face is the one in second row, first column. The neural network, used to train the system, is a three layer backward propagation neural network. There are 12, 4, 1 cells in each of the layer, respectively. The logsig function is used as the transfer function. The network was first trained by a batch wok, then fine tuned by incremental training with other variations, such as glasses wearing faces, big round-eye faces, long faces, round faces etc.

We recognize the best-detected faces to decide whether the accesses are granted. The number of sizes is determined by the image-taken-region in front of the entrances. The number of different face orientations is determined by the degree of the up-right of the users' faces we expect. This detection algorithm makes no pre-defined-assumptions on the background. For example, first, we have a face image with moving clustered background (as in Fig. 3):

Fig.3

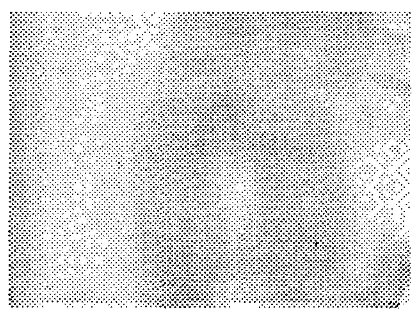

Fig. 4

Then, we want to find a face which includes from the eyebrow to the upper lips, the correlation coefficient result calculated in Figure 4, as in two-phase face detection algorithm[1], the binarized matching results are shown in Figure 5, and the calculated possible facial region is shown in Figure 6.

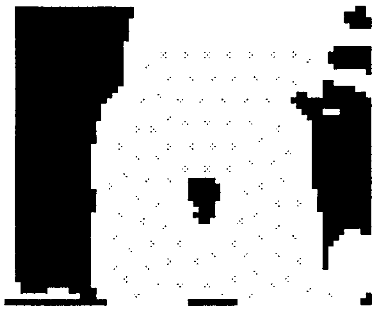

Fig. 5

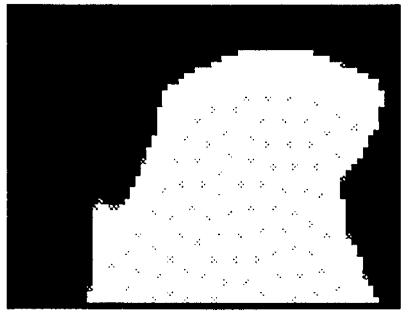

Fig. 6

To combine Figure 4 and Figure 6, the "face" is detected in Figure 7. Have the detected face in full resolution, Figure 8, the eyes and the eyeballs and the nose are located and length measured.

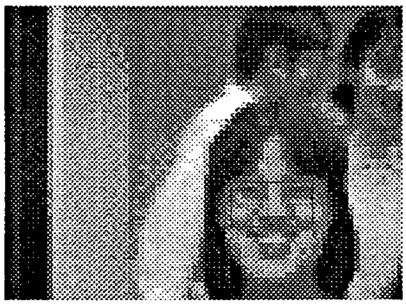

Fig. 7

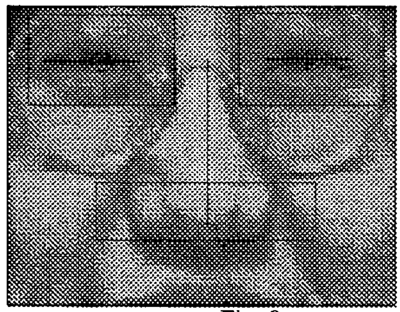

Fig. 8

For the techniques mentioned in the first section, the recognition can be decomposed as representation and matching. A good representation of an object carries the enough information toward the goal, but also saves the storage space and the computing time. While a good matching algorithm takes the minimum information produces a well-separated decision space for decision-making.

Since human being carries different habits and tendency. The variations of their features are quite different too. To collect all authorized personnel information in one space, the information of each person's each feature variation can be imbedded in the variation of multivariable-normal distributions. The metric of the decision space, the distance of the sample point to each person may be defined by each person's multivariable probabilities.

A simple feature as facial length measurements is employed to recognize faces for a small number of authorized personnel. The length measurements of each person is roughly normal distribution: Figure 9 shows the distance between two eyes (from the left eye inner point to the right eye inner point) are fairly good Gaussian distribution. The Figure 10 and Figure 11 shown left and right eye length, respectively, the normality test is good too.

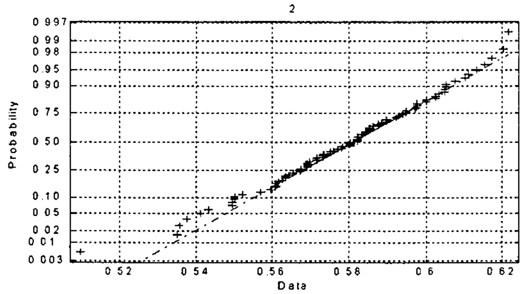

Fig. 9

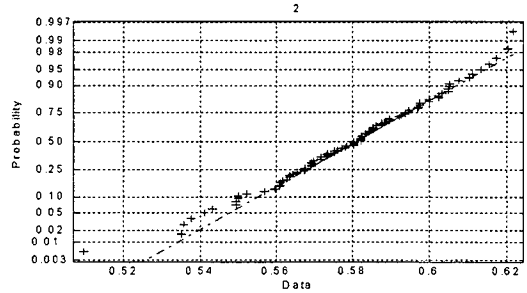

Fig. 10

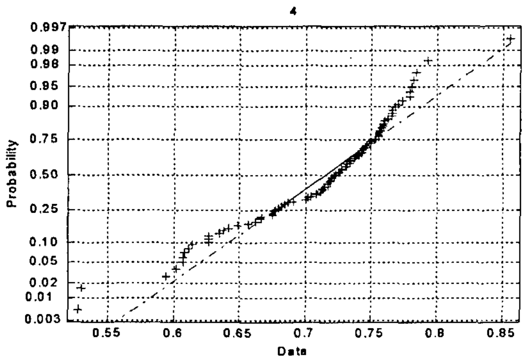

Fig.11

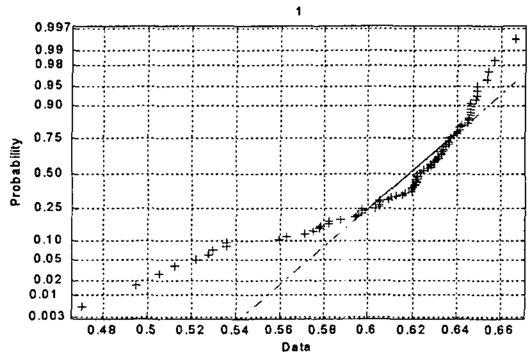

Fig. 12

Figure 12 is the eyeball-distance normality test. Figure 13 is the nose length normality test. While the Figure 14 is the normality test for nose width. The nose width and the eyeball distance are not quite well fit into normal distribution, especially, the nose width. Since the Nose is a 3D feature in the face, the face forward direction has non-linear influence on the nose width measure.

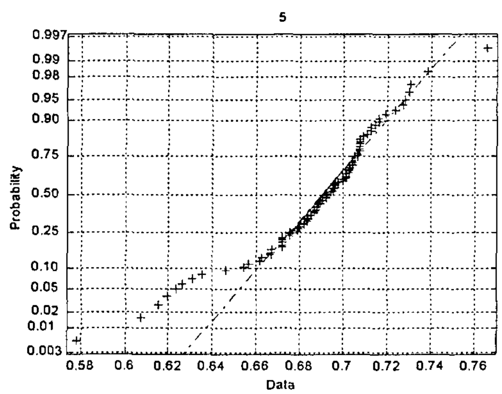

Fig. 13

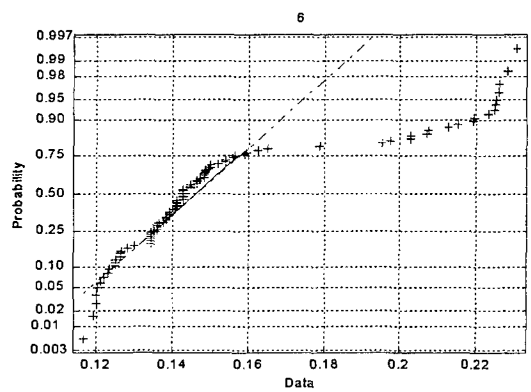

Fig. 14

Theoretically speaking, we can increase the number of features to increase the recognition population, therefore, split the nose width into 3 measures may improve the fitting. Then with the set of features, the multi-variable normal distribution of each person is determined by analyzing a sample series of facial image .

3. RESULTS

The program constitutes two parts (Fig. 15): building database for authorized personnel and face recognition. We take ten length measurements in each face. In the "building database for authorized personnel" part, we take 35 "good" (some face image are not quite frontal views which cause the measurements abnormal) samples for each person to calculate the multi-variable normal distribution as personal parameters. When the person is not facing the camera or the face is not detected, the algorithm will continuously take images and do facial measurements analysis, then recognize the face. In each "face recognition", the facial measurements taken from the face image are used to calculate the personal

probability for every person in the database. When the maximum conditional probability is greater than the threshold value, the face image is identified.

With Matrox Meteor II frame grabber on Pentium II, clock speed 400 MH, 192 MB RAM, the visual C++ program did the face recognition in 3 to 4 seconds in each round. We project this algorithm ought to be fast enough for real time operation with DSP parallel processing chip. We obtained 86% correct recognition rate among 5 persons, each person with 30 times of recognition. For there are still room for the improvements of the facial length measurements taken and measurement choices, we expect the algorithm is able to do better.

4. SUMMARY

In this paper, we proposed a face recognition algorithm for the security entrance systems. This algorithm does not interrupt the proceeding of the users, does not need the users pay special attention to the security system, as long as the users don't turn their faces away from the Image taking camera during the image-taken region. There is no assumption on the background. This algorithm also tolerates the up-right variation of the face-tilting as the face-tilting angle desired. This algorithm will suffice the small-authorized personnel entrances, such as small companies, laboratories, or home, small dormitories.

There are a few things can improve the result further. As the Figure 14 indicates the nose width is a poor length measurement choice for normal distribution. While nose width is an important feature in human faces. Use EM method to model the human nose width may be better improve the recognition results.

5. ACKNOWLEDGEMENTS

This work was supported by the Opto-Electronics & Systems Laboratories, the Industrial Technology Research Institute, Republic of China.

6. REFERENCES

1. C. W. Ni, "The Tracking 3D Display Systems by Image Processing Analysis", *SPIE Proceedings* vol. 3296, pp. 217-224, Jan. 1998.
2. Shang-Hung Lin, Sun-Yuan Kung, and Long-Ji Lin, "Face Recognition/Detection by Probabilistic Decision-Based Neural Network," *IEEE trans. Neural Networks*, Vol. 8, pp. 114-132, Jan. 1997.
3. S. Lawrence, L. Giles, and A. C. Tsoi, "Convolutional Neural-Network for Face Recognition," *Proc. IEEE Conf. on Computer Vision and Pattern Recognition,* pp. 217-222, 1996.
4. H. A. Rowley, S. Baluja, and T. Kanade, "Neural Network-Based Face Detection", *Proc. IEEE Conf. on Computer Vision and Pattern Recognition,* 1996.
5. I. J. Cox, J. Ghosn, and P. N. Yianilos, "Feature-Based Face Recognition Using Mixture-Distance", *Proc. IEEE Conf. on Computer Vision and Pattern Recognition,* 1996.
6. M. A. Shackleton, and W. J. Welsh, "Classification of Facial Features for Recognition", *Proc. IEEE Conf. on Computer Vision and Pattern Recognition,* 1991.
7. M. A. Turk, and A. P. Pentland, "Face Recognition Using Eigenfaces", *Proc. IEEE Conf. on Computer Vision and Pattern Recognition,* 1991.
8. T. Darrell, B. Moghaddam, and A. P. Pentland, "Active Face Tracking and Pose Estimation in an Interactive Room", *Proc. IEEE Conf. on Computer Vision and Pattern Recognition,* 1996.
9. M. A. Turk, and A. P. Pentland, "Face Recognition System", *U. S. Patent, No. US5164992,* 1992.
10. Jun Zhang, Yong Yan, and M. Lades, "Face Recognition: Eigenfaces, Elastic Matching, and Neural Nets," Proc. Of the IEEE, Vol. 58, No.9, pp. 1423-1435, Sept.1997.
11. L. P. Ammann, "Robust Image Processing for Remote Sensing Data", Proceedings of 1st International Conference on

Image Processing, Austin , pp. 41-45, 1994.

12. Xing Wu and Bir Bhanu, "Gabor Wavelet Representation for 3-D Object Recognition", *IEEE trans. on Image Processing*, Vol. 6, pp. 47-64, Jan. 1997.
13. K. S. Yoon, Y. K. Ham, and R.-H. Park, "Hybrid Approaches to Frontal View Face Recognition Using the Hidden Markov Model and Neural Networks", *Pattern Recognition,* Vol. 31, no. 3, pp. 283-293, 1998.

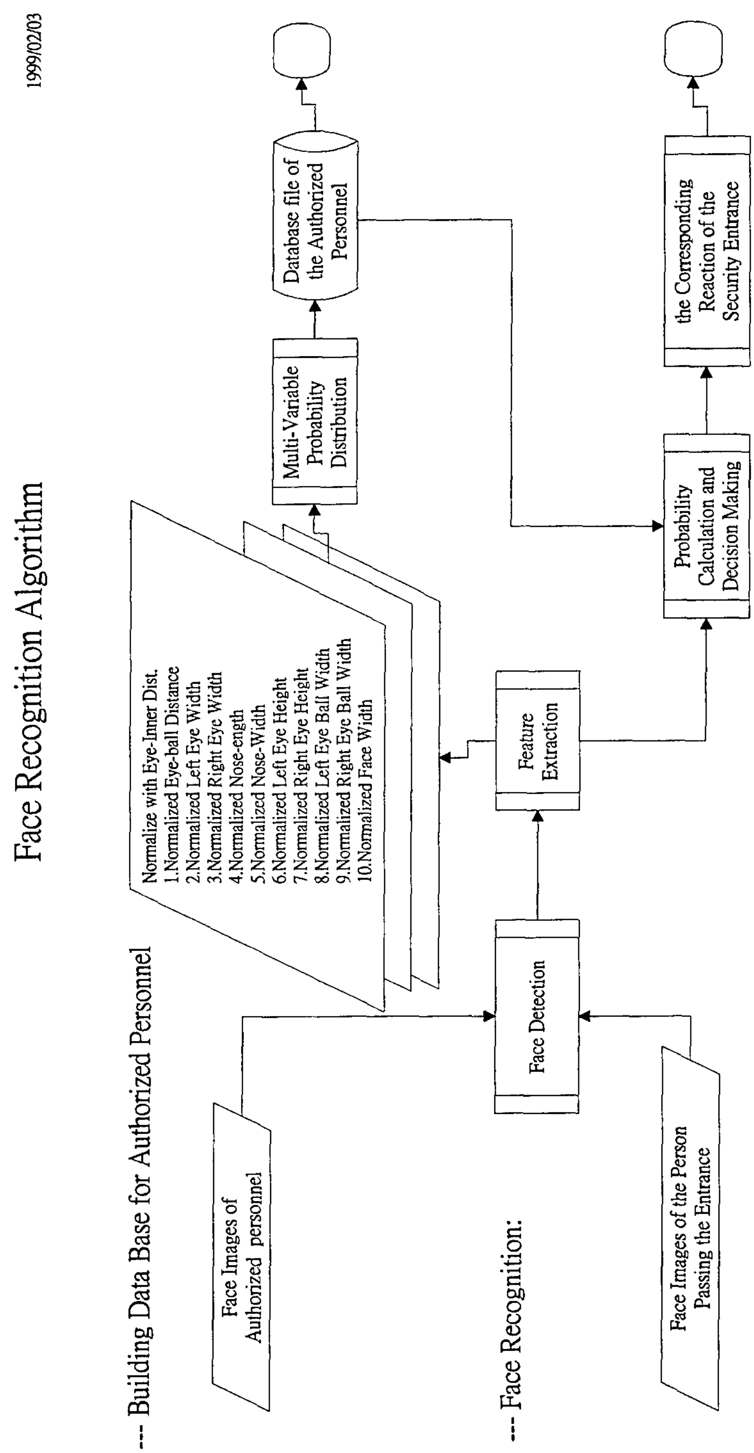

Fig.